OBLIQUE WING AERODYNAMICS

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ABSTRACT

The aerodynamic performance of a wing at an oblique deployment orientation has been found through wind tunnel testing to affect both the lateral and longitudinal stability of a cruise missile. While conventional analysis tools are insufficient for calculating the aerodynamics of an oblique wing, a suitable method has been determined for use with the USAF Missile DATCOM code. Comparisons made between wind tunnel results and Missile DATCOM calculations show that Missile DATCOM can produce a reasonable approximation of the aerodynamics of a wing at oblique deployment angles.

1. INTRODUCTION

A need has developed for a cruise-type surveillance missile that can be fired from a helicopter and retrieve information from the battlefield. Such a missile requires a large lifting surface to produce the necessary range and time of flight. However, the primary lifting wing must be minimized to maximize the number of missiles carried. Reducing the wing area is unacceptable as it would compromise the flight time. Hence, the wing must be stowed and deployed after launch. The deployment process under investigation transitions the wing though oblique angles to the traditional wing orientation, i.e. perpendicular to the body.

The topic of interest is the resulting change in the normal force, pitching moment, center of pressure, and rolling moment as the wing deploys. Modeling asymmetric missile geometries with standard aerodynamic design codes is difficult. However, Missile DATCOM may be modified to model such a wing. Measured results and comparisons with modified DATCOM calculations are presented in the following sections of this paper.

2. WIND TUNNEL CONFIGURATION

A high-mounted, swing-wing missile was tested in the Texas A&M University Low Speed Wind Tunnel at Mach 0.25. The test article was a ten caliber long body with a wing mounted on top. The wing was 40 inches in span while the chord was six inches, with a NASA MS-313 cross section. The mounting mechanism fixed deployment angles at 0, 22.5, 45, 67.5, and 90 degrees as measured from the leading edge of the wing to the centerline of the body. The angle of attack range measured in the tunnel was -5 to 14 degrees, but the size of the model required that data at negative angles of attack be obtained by rolling the model 180 degrees and pitching up.

3. MISSILE DATCOM SETUP

The USAF Missile DATCOM (Blake, 1998) can be used to analyze complex configurations if care is taken when interpreting the results. Missile DATCOM can be used to model a high-mounted wing by using a fin set with two fins both placed at $\Phi=0$, i.e. the top of the body with the fins vertical. One fin can then be given a dihedral of 90 degrees and the other a dihedral of -90 degrees in order to rotate the fins to the horizontal plane.

In order to obtain the proper wing sweep, two fin sets must be used, with each one containing one fin. Both sets are located at the same longitudinal station. One fin is given a negative, or forward, sweep angle, while the other fin is given a positive, or aft, sweep angle of the same magnitude.

The wind tunnel configuration was modeled using the above procedure. However, due to the limitations of the user defined airfoil entry, a NASA 2613-64 airfoil cross section was used instead of the actual cross section. This airfoil provided the best approximation to the actual camber, $CN\alpha$, and CL_0.

4. RESULTS

Comparisons with measurement determined that Missile DATCOM produces erroneous or improbable results for deployment angles less than 30 degrees. However, at deployment angles above 30 degrees, the results appear to be legitimate.

Figures 1 through 3 show these comparisons for δ=45, 67.5, and 90 degrees. Error bars are included on the wind tunnel data for reference (Holman, 2001). At δ=45 degrees, there is less than a 10 percent difference for normal force and pitching moment. The difference rises to nearly 20 percent once the wing is fully deployed. It is likely that the difference in airfoil

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characteristics causes some of the discrepancies. It should be noted that the predictive differences translate to about a 0.1 caliber change in the center of pressure location for all three deployment angles.

Missile DATCOM fails to capture either the sudden counterclockwise rolling moment below -10 degrees AOA for δ=45 degrees or the increased clockwise rolling moment above 8 degrees AOA for δ=67.5 degrees.

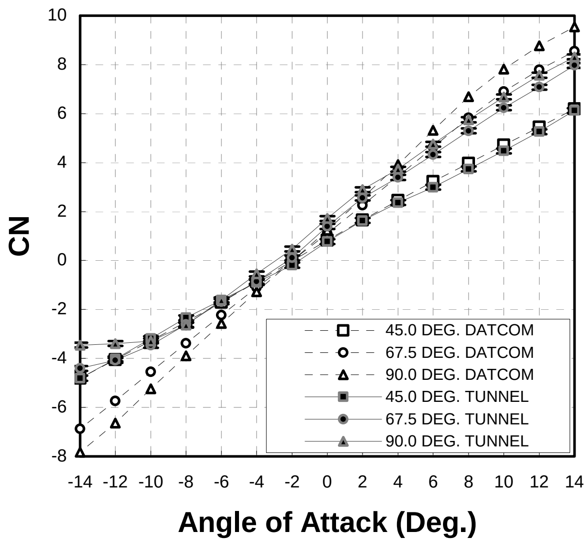

Fig. 1 Normal force comparison

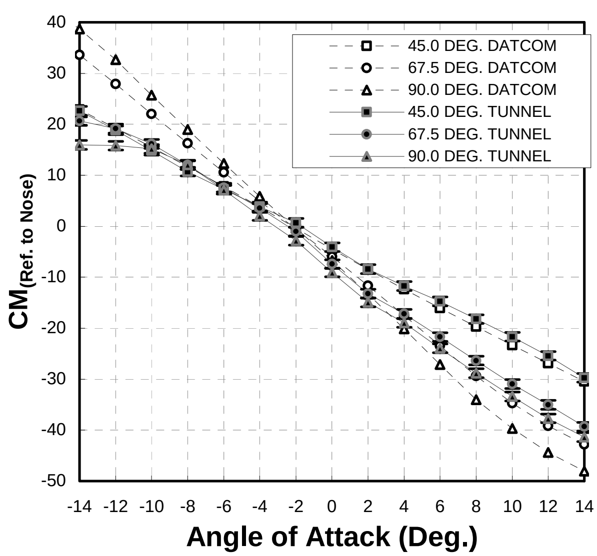

Fig. 2 Pitching moment comparison

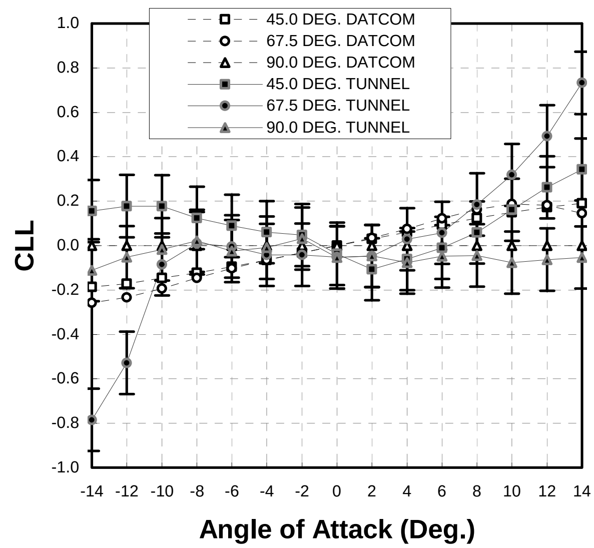

Figure 3: Rolling moment comparison

CONCLUSION

Using a swing wing that deploys during flight presents stability and analysis challenges for the airframe and designer. A shifting center of pressure means that the designer will have to carefully size and place tail fins that are capable of handling stability shifts. Additionally, the missile must have sufficient roll control to compensate for the induced roll of the wing deploying.

Wind tunnel testing is a reliable method for analyzing this type of missile; however, the need for responsiveness during the design process does not always allow time for such testing. Exploitation of the flexible data inputs of Missile DATCOM allowed development of a method to compute the longitudinal aerodynamics of the wing as it deploys. This method appears sufficient to predict the center of pressure within 0.1 calibers for most cases. However, it can not be used for deployment angles below 30 degrees. Additionally, it does not capture the lateral aerodynamics well. Wind tunnel testing indicates large shifts in stability as the wing initially deploys. As a result, the angles where DATCOM can not predict the aerodynamics may be the most critical points. In order to capture the aerodynamics in these regions a wind tunnel test or a CFD solution would be necessary.

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Blake, "Missile DATCOM: User's Manual – 1997 FORTRAN 90 Version," Air Force Research Laboratories Document AFRL-VA-WP-TR-1998-3009, Feb. 1998.

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